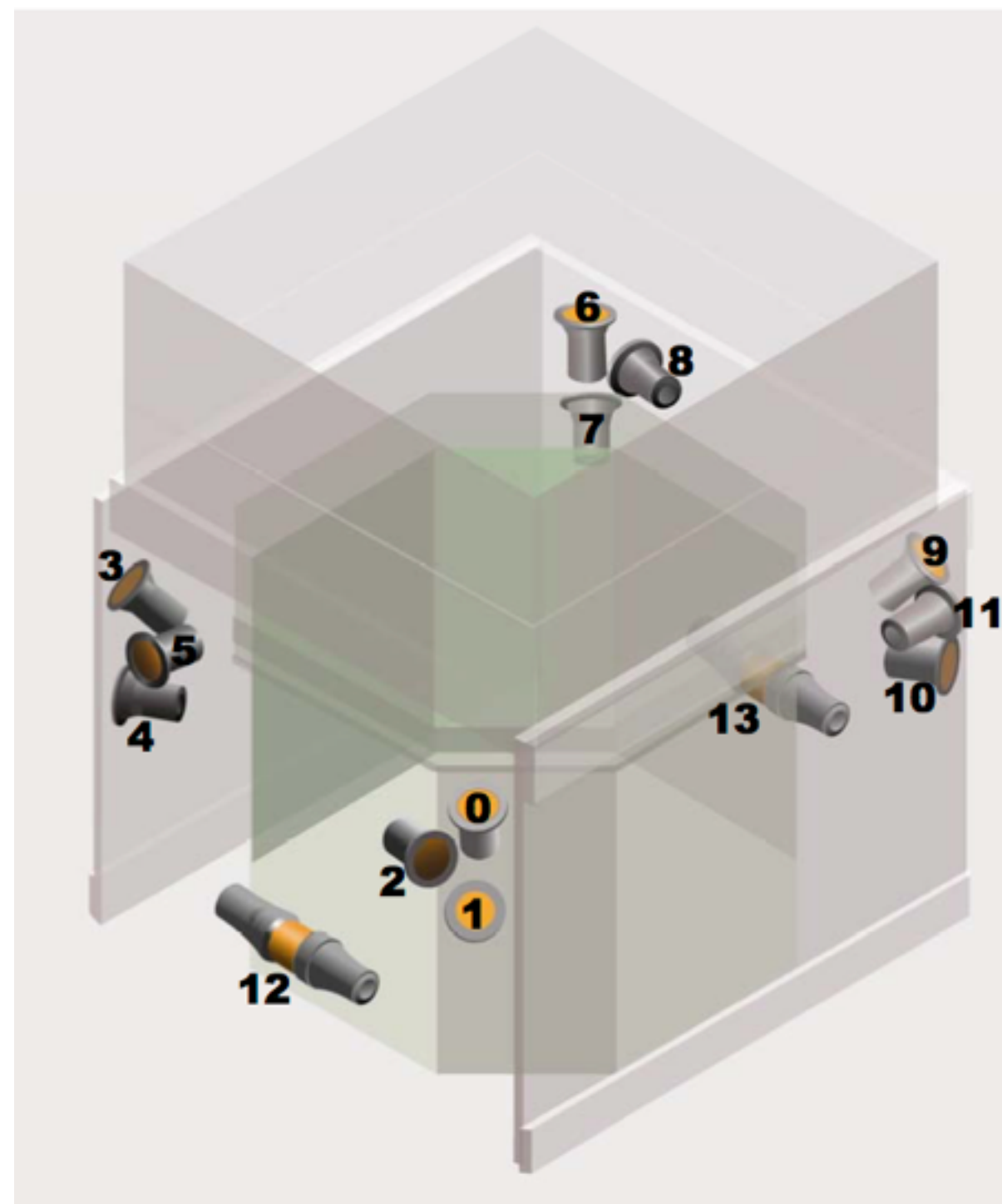


Time-domain Astronomy with *Fermi* GBM

C. M. Hui (NASA/MSFC)
on behalf of the *Fermi* GBM team

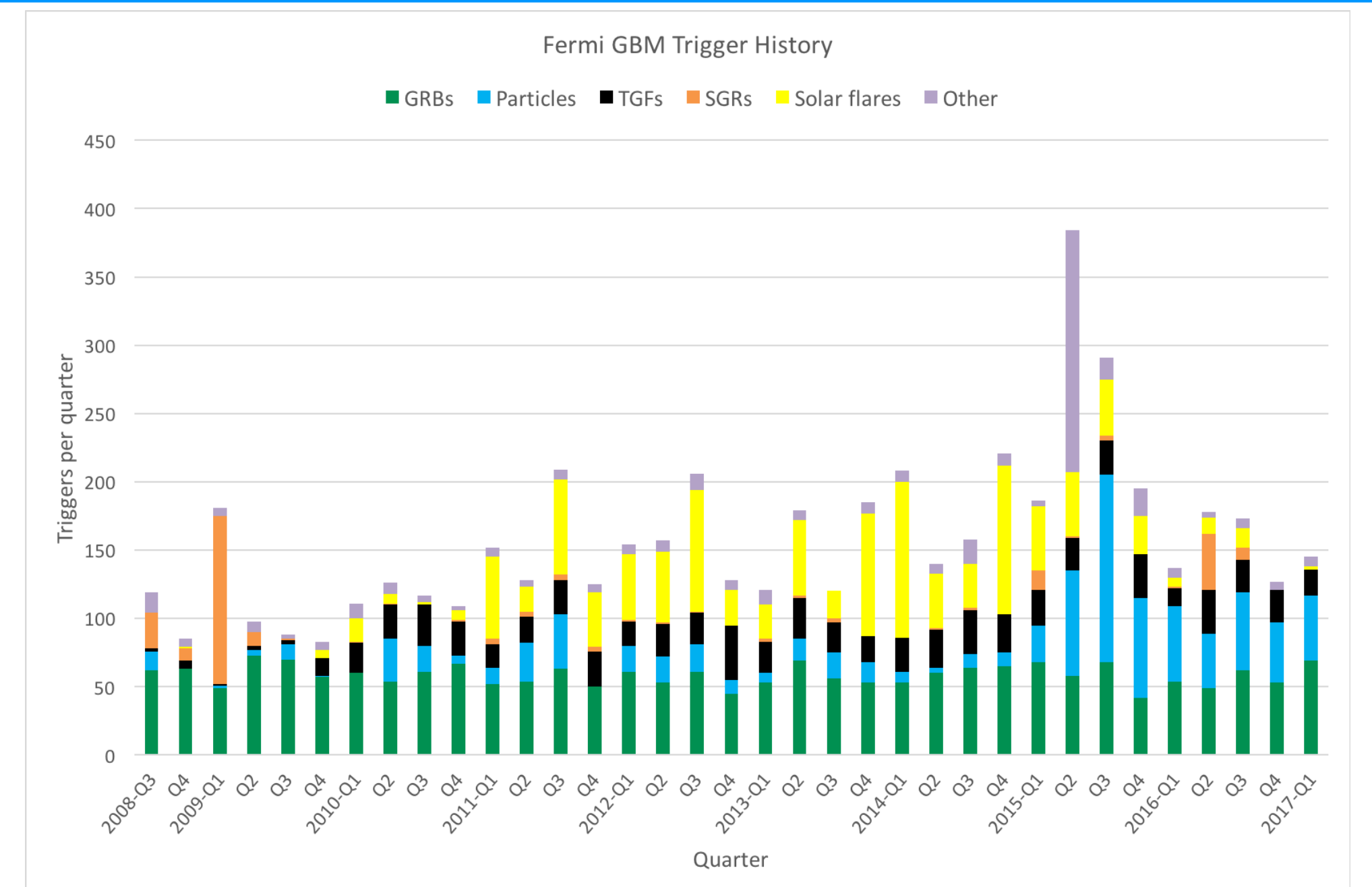
The Fermi Gamma-ray Burst Monitor (GBM) is an all-sky monitoring instrument sensitive to energies from 8 keV to 40 MeV. Over the past 8 years of operation, the GBM has detected over 240 gamma-ray bursts per year and provided timely GCN notices with localization to few-degree accuracy for follow-up observations. In addition to GRBs, Galactic transients, solar flares, and terrestrial gamma-ray flashes have also been observed. In recent years we have also been searching the continuous GBM data for electromagnetic counterpart to astrophysical neutrinos and gravitational wave events, as these are believed to be associated with gamma-ray bursts. With continuous data downlink every few hours and a temporal resolution of 2 microseconds, GBM is well suited for observing transients and supporting EM followup in the era of multi-messenger astronomy.

The GBM instrument



- 12 NaI detectors, sensitive from 8 keV to 1 MeV.
- 2 BGO detectors, sensitive from 200 keV to 40 MeV.
- > 8 steradians field of view and sample entire sky every ~90 minutes.
- 120 distinct triggers are possible, from a combination of 4 energy ranges (25+ keV to >300 keV), 10 timescales (16ms — 8.192s).
- Available data products:
 - CTIME data (256ms temporal resolution and 8 energy channels)
 - CSPEC data (4s temporal resolution and 128 energy channels)
 - CTTE data (2μs temporal resolution and 128 energy channels)

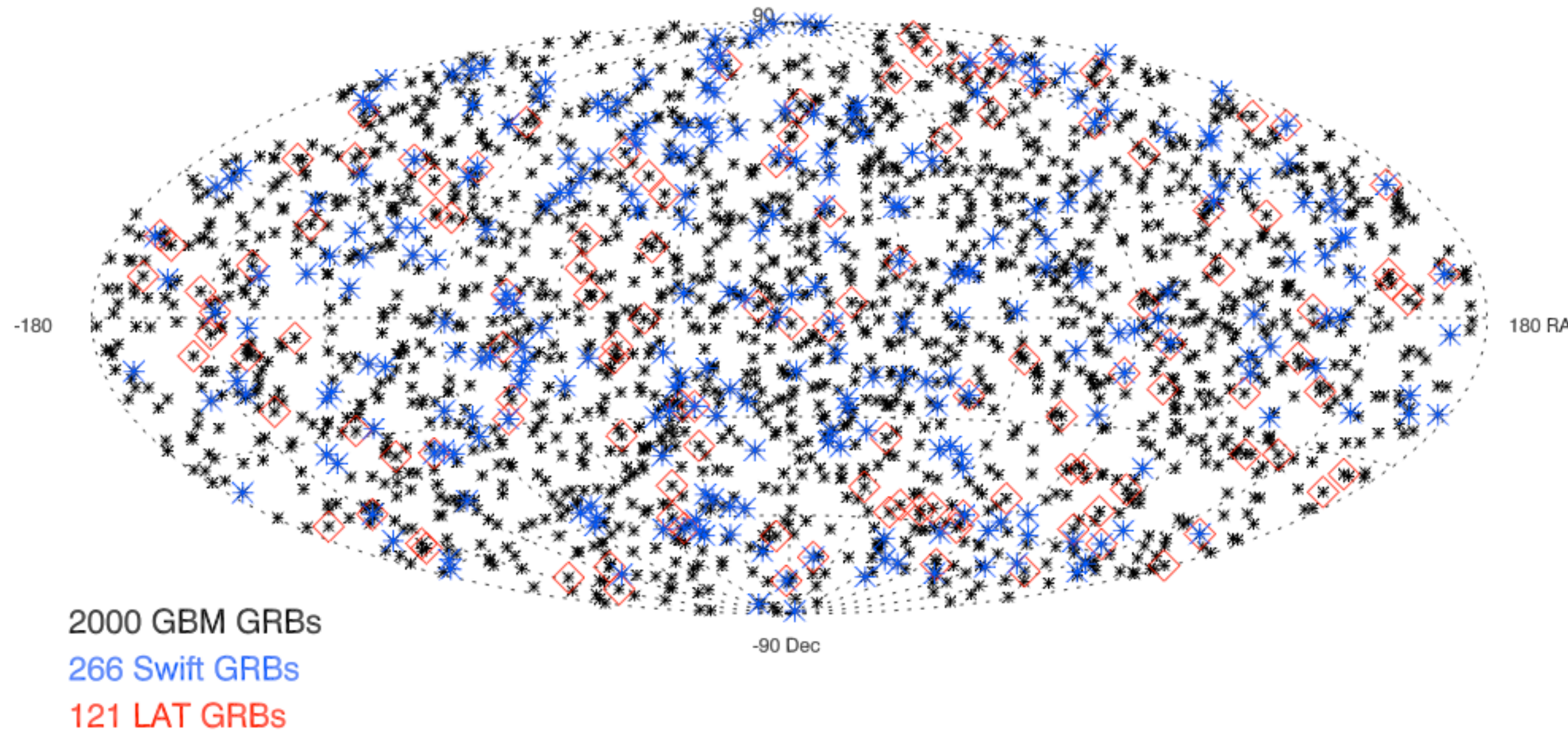
Left: GBM detectors on the *Fermi* spacecraft. Detector 0—11 are NaI detectors; detector 12 and 13 are BGO detectors.



Above: Quarterly trigger classification. In addition to GRBs, 47% of triggers are other astrophysical sources and phenomena such as Galactic transients, terrestrial gamma-ray flashes, and solar flares.

Gamma-ray Bursts

2000 Fermi GBM GRBs

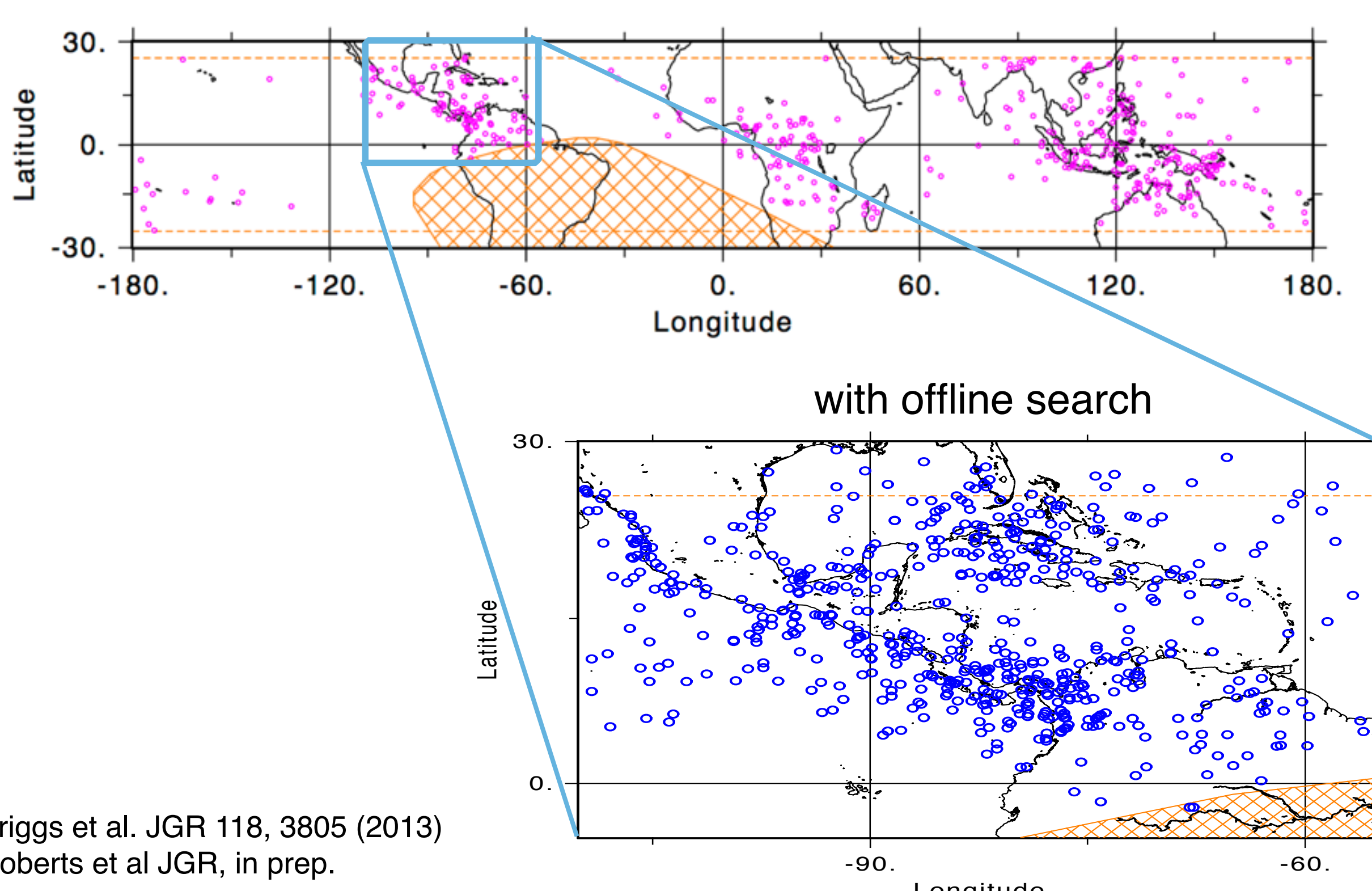


- Over 2000 GRBs have been detected since launching in 2008:
 - ~200 long GRBs /year, massive star collapse
 - ~40 short GRBs /year, compact merger event
 - 13% seen by Swift
 - 52% within *Fermi* LAT FOV, 6% is also seen

Terrestrial Gamma-ray Flashes

- Intense and short (millisecond timescale) gamma rays produced in Earth's atmosphere.
- Associated with electrons accelerating in electric fields at the top of thunderstorm clouds.
- Present in triggered events and dedicated offline data search.
- Online catalog has 4144 TGFs between 2008 and 2016.
 <https://fermi.gsfc.nasa.gov/ssc/data/access/gbm/tgf/>

425 Fermi GBM Triggered TGFs through 2014 January



Briggs et al. JGR 118, 3805 (2013)
Roberts et al JGR, in prep.

Pulsar Monitoring

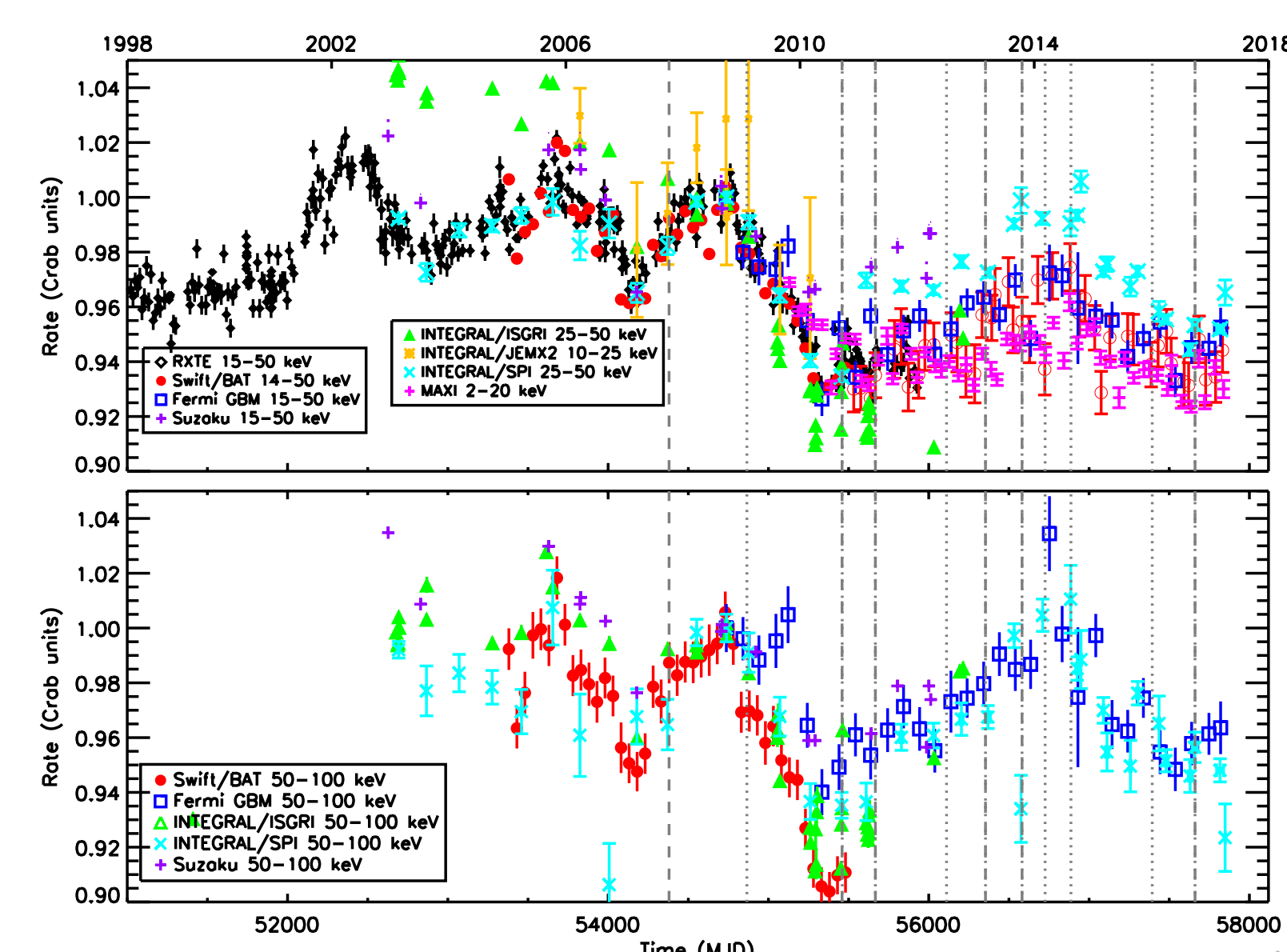
- Accreting pulsars are detected by the frequency modulation. Currently monitoring:
 - 8 persistent pulsars
 - 28 transient pulsars

<https://gammaray.nsstc.nasa.gov/gbm/science/pulsars.html>

Monitoring by Earth Occultation Technique

- 200+ sources are monitored, from X-ray binaries to Active Galactic Nuclei
- 102 detections, 9 at >100 keV

https://gammaray.nsstc.nasa.gov/gbm/science/earth_occ.html

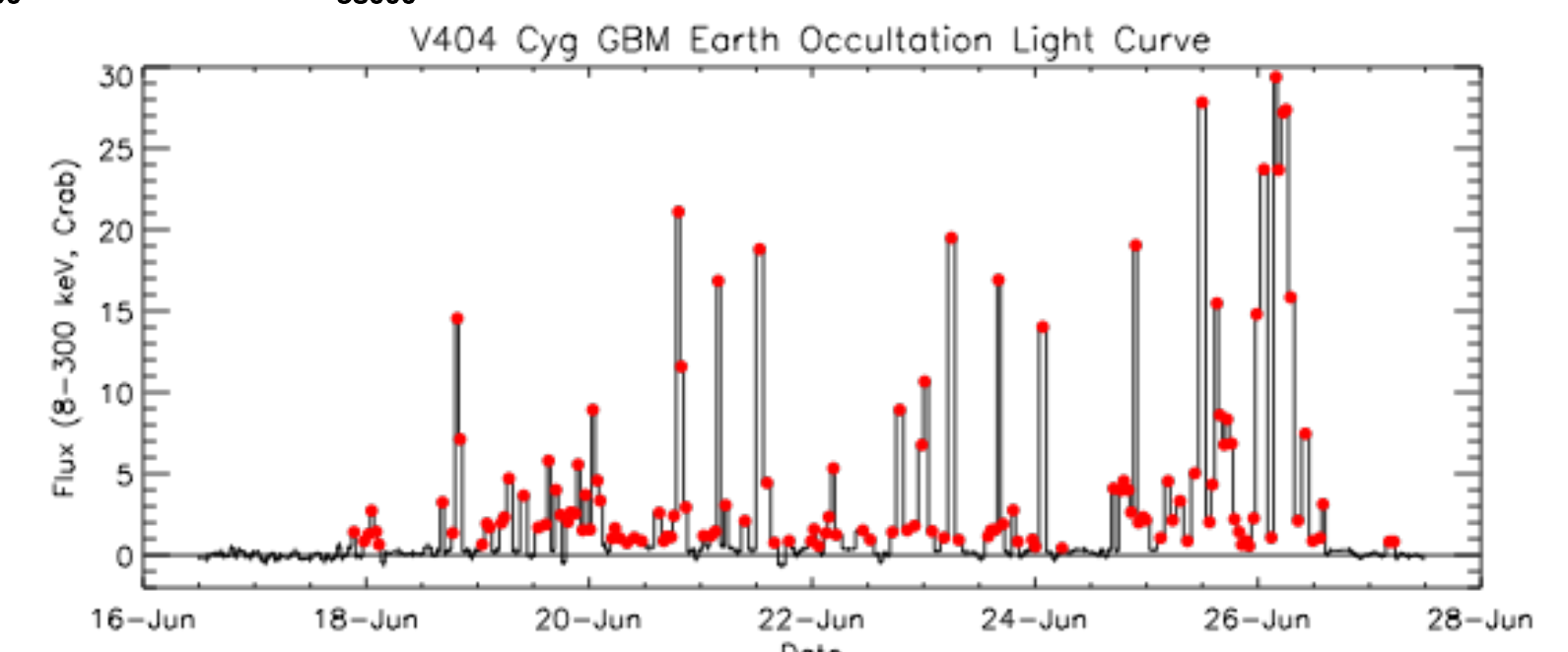


Left: Crab Nebula flux variations over the past decade, averaging at 10% and up to 40% at 300—500 keV.

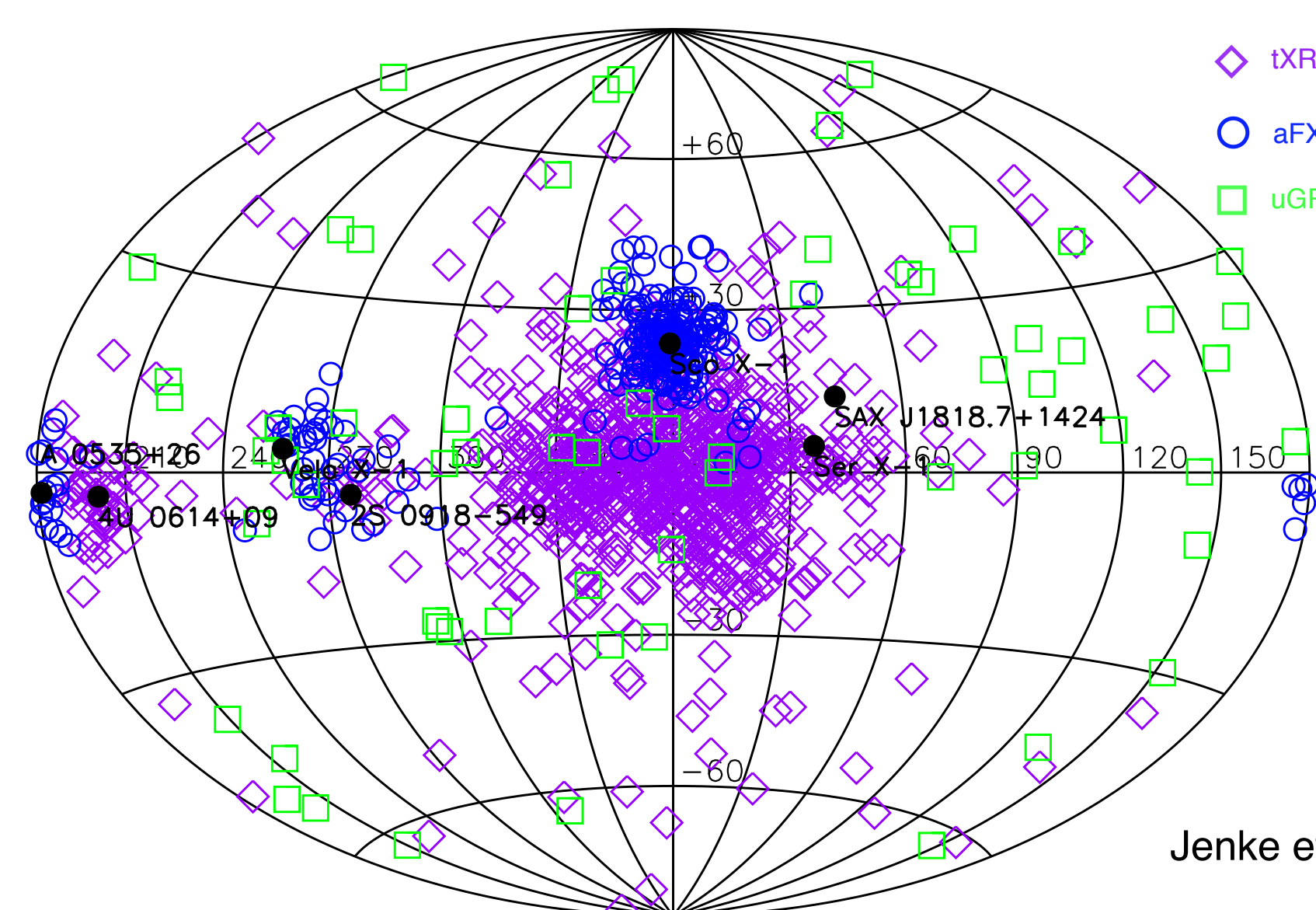
Wilson-Hodge et al. ApJ 727, 40 (2011)
Wilson-Hodge et al, in prep.

Right: Black hole binary system V404 Cyg outburst in 2015. Over a period of 13 days, flux reached up to 30x Crab.

Jenke et al. ApJ 826, 37 (2016)



X-ray Bursts



Jenke et al. ApJ 826, 228 (2016)

Above: 1084 X-ray bursts detected by GBM between 2010 and 2013 in Galactic coordinates. Purple diamonds are thermonuclear X-ray bursts, detected 1.4 per day at a distance of <10kpc and average blackbody temperature of 3.2 +/- 0.3 keV.

Blue circles are accretion flares and X-ray pulses, many cluster around Sco X-1, A0535+26, and Vela X-1.

Green squares are untriggered GRBs.